The morphology, ethology and palaeoecology of certain trace fossils from the Jurassic rocks of England

Farrow, George Ernest

Plate One

The North Sea coast of northeast Yorkshire south-southeast of Blea Wyke Point, showing the backshore from which many trace fossils described in the text were collected.

Photograph taken from the track which leads down the cliff from Ravenscar under the Coast-guard hut.

The feature at the top of the undercliff is made by the Ellerbeck Bed.

Plate Two (A)

The North Sea coast at Cloughton Wyke, showing the limited "spray-zone" where trace fossils are well preserved, beneath which algae prohibit examination.

The cliff is formed of the higher Middle Deltaic Series.

Plate Two (B)

The "Spray-Zone" immediately north of Cloughton Wyke, showing the abundance of fallen material in the form of large tabular blocks of ideal size for the application of the Quadrat technique.

The blocks with excellently developed parting lineation come from a persistent sandstone in the Middle Deltaic Series.

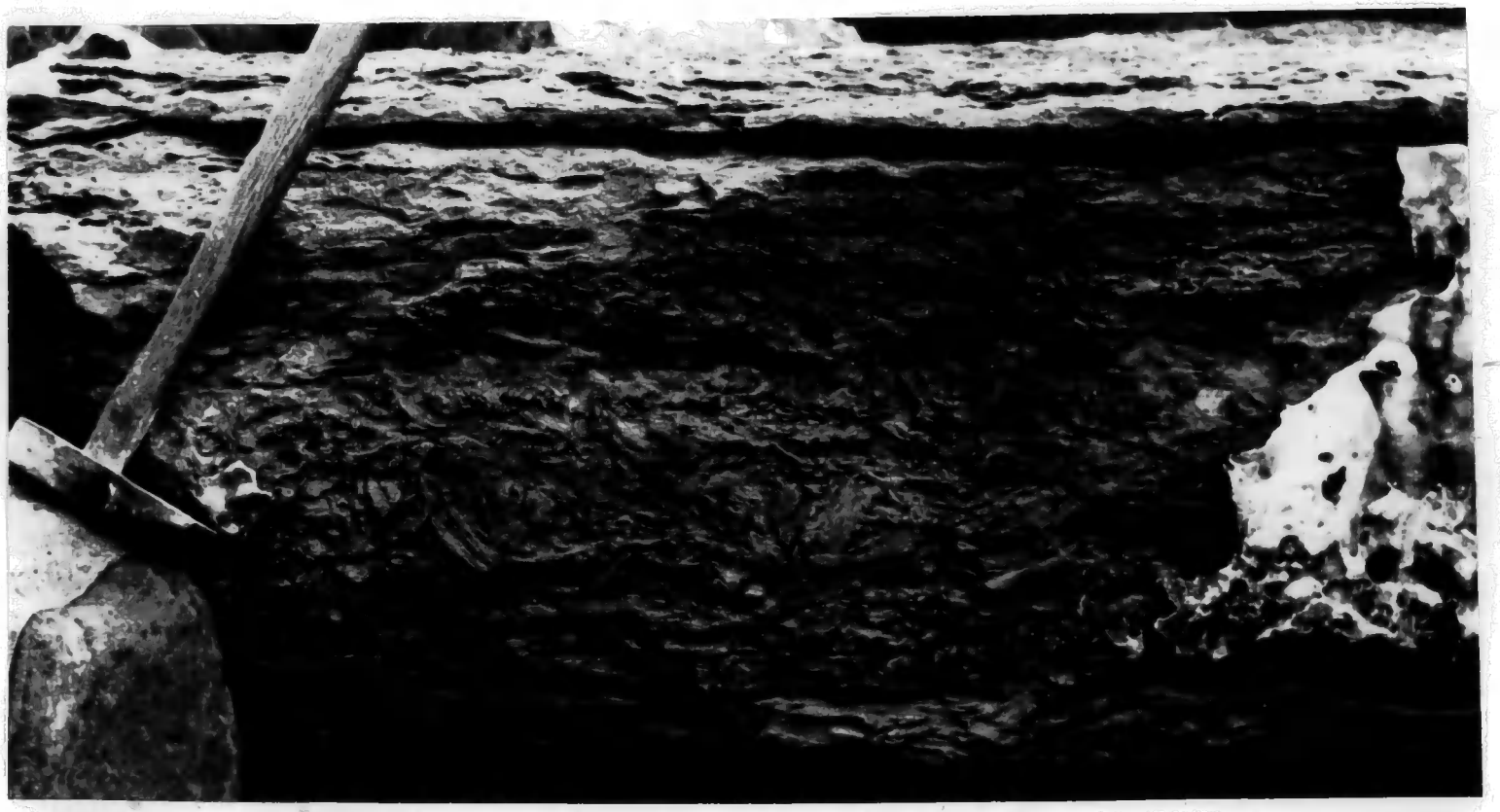

Plate Three

Vertical section of loose block of S.B.32, a sandy limestone from the Scarborough Beds of Ravenscar, showing almost 100% re-working by burrowing organisms, with the complete destruction of original bedding.

Plate Four

Two loose blocks of Lower Liassic Mottled Marl on the foreshore west of Lyme Regis, showing diagenetically enhanced preservation of the trace fossils *Thalassinoides*, *Coprophioides lymensis*, *Chondrites* and *Rhizocorallium*.

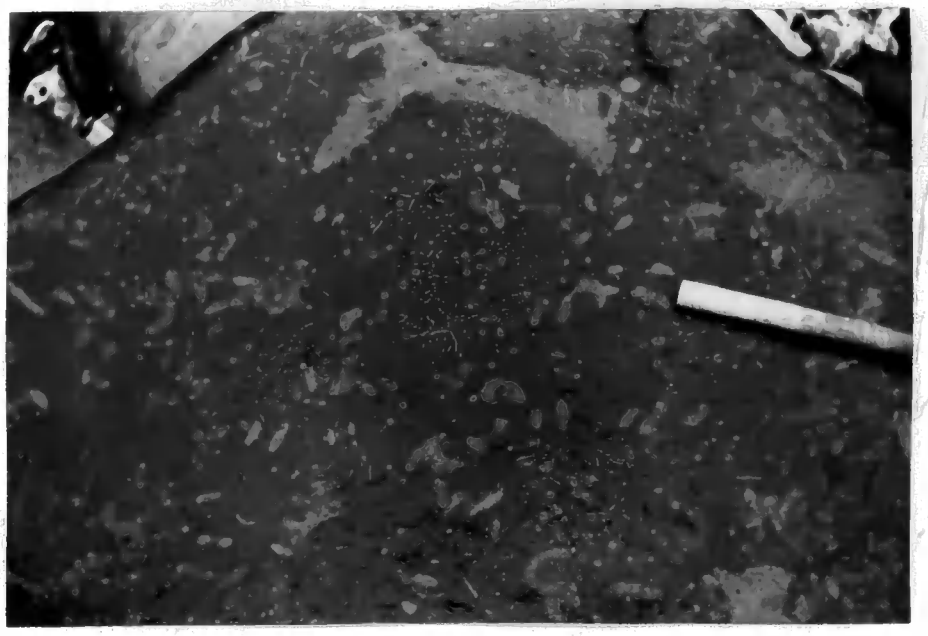

Plate Five

Close-up of *Corophioides lymensis* (right) and *Rhizocorallium jenense* (left) from the base of the Ellerbeck Bed beneath Staintondale, showing the preservation of delicate scratch markings on the walls of burrows impressed into very fine-grained kaolinitic silts of the Lower Deltaic Series. x 10

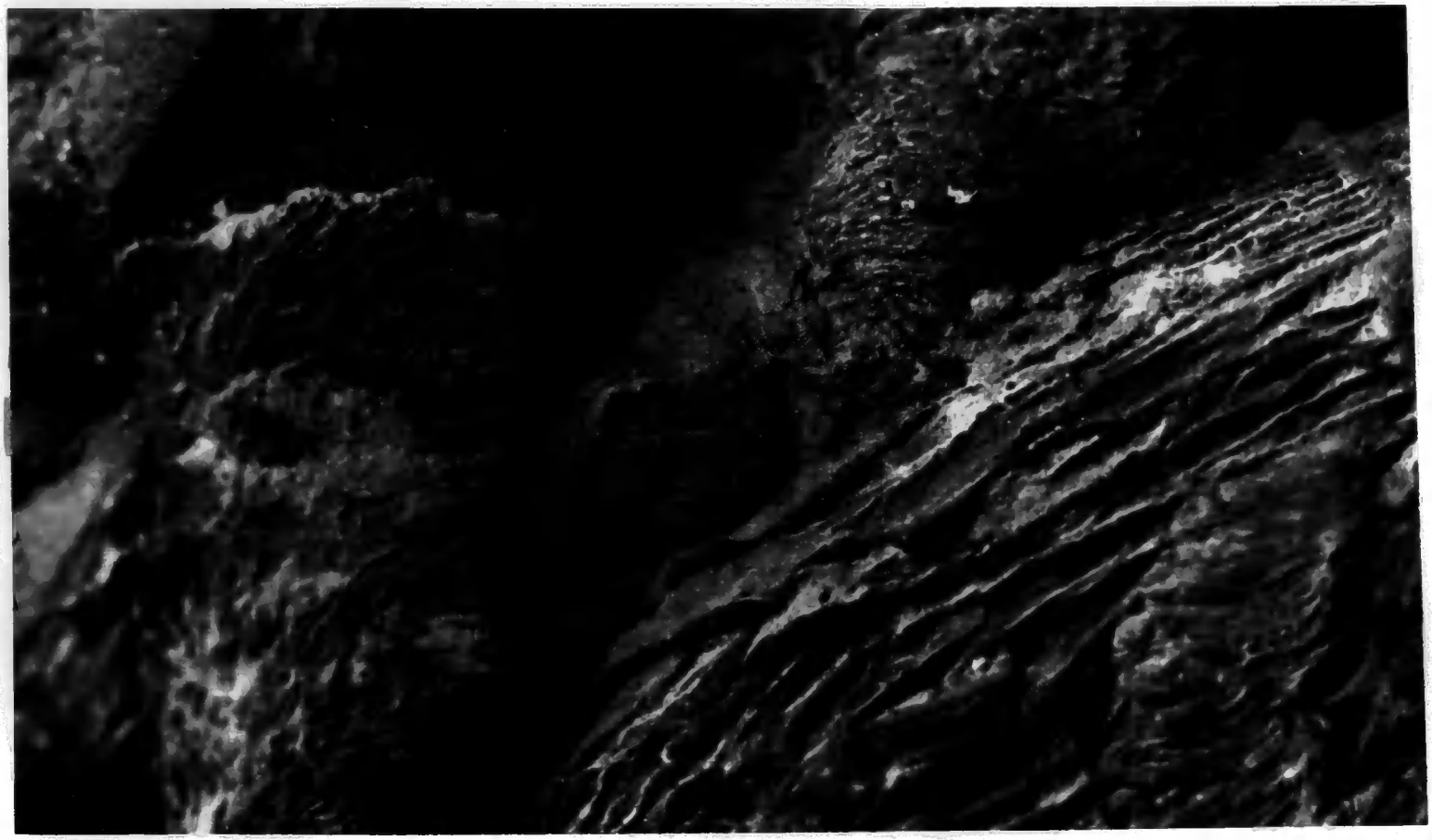

Plate Six

Recent colony of *Arenicola marina* in littoral mud, Sandsfoot, Dorset.

Note the varying preservation of the inhalent funnel due to differences in thixotropy.

Plate Seven

Recent trails of Littorina littorea preserved in littoral mud.

A. Close-up of typical trail made in mud with low thixotropy; notice the marked transverse ridges (HANTZSCHEL)

B. General view of trail showing the variable preservation of the transverse ridges, caused by thixotropic differences (HANTZSCHEL): scale = 10 cm.

C. General view of a set of parallel trails with very pronounced lateral ridges but poor transverse ridges, constructed under thin sheet of water (FARROW): pencil = 9 cm.

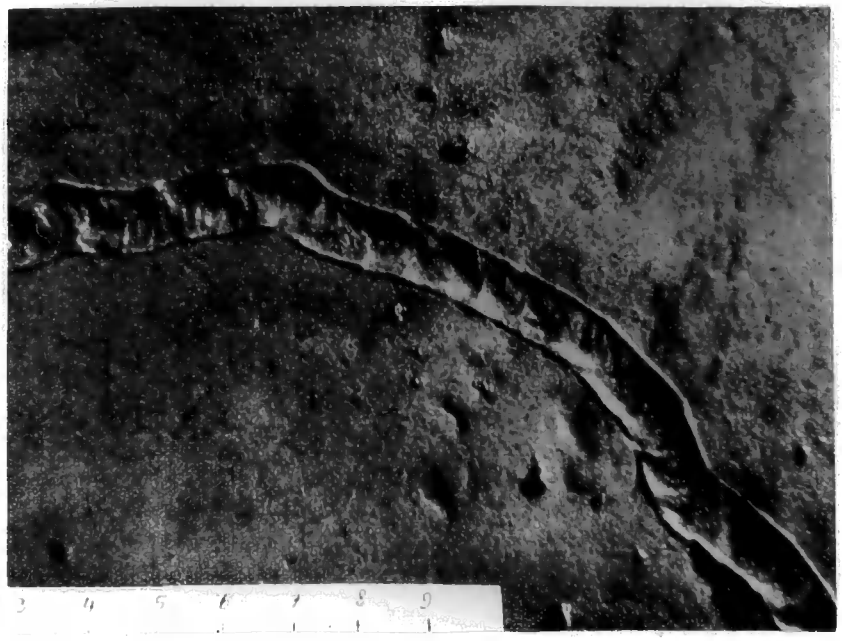


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Plate Eleven

Arenicolites skeltonensis sp. nov. from basal Upper Lias, immediately above the Sulphur Band, North Skelton.

Top. Type specimen, showing the striking bed-junction preservation, associated *Chondrites*, and black burrow-lining. Note the burrow with the funnel penetrated by protrusive laminae to the right of the photograph.

Bottom. Specimen showing the highly polished burrow walls and the tube constrictions caused by resistant bands in the siderite mudstone.

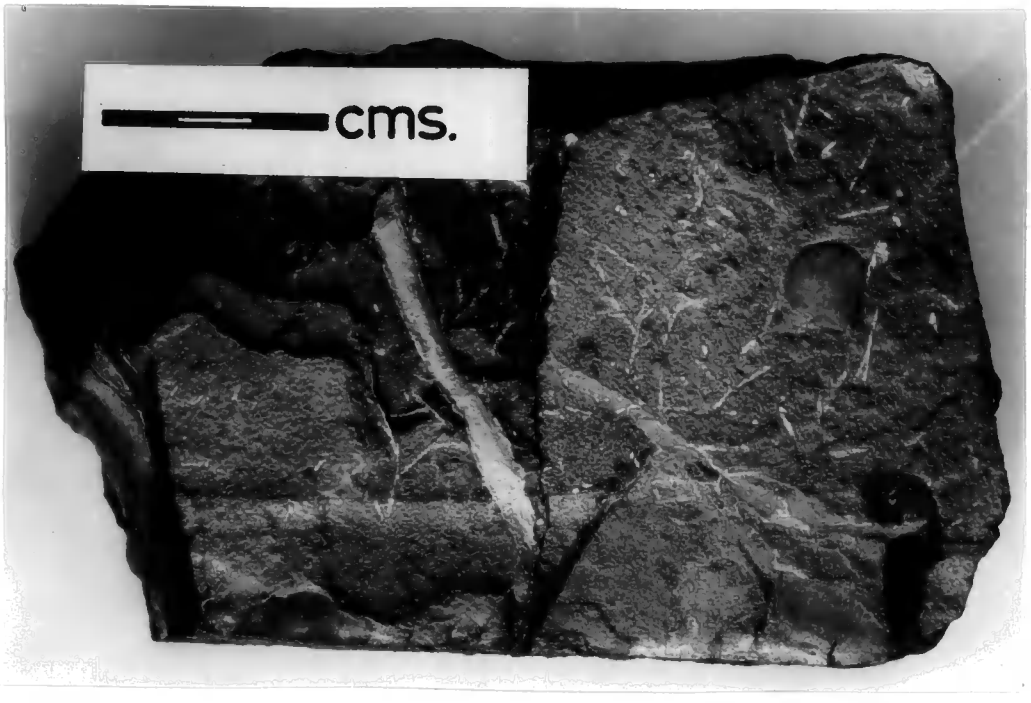
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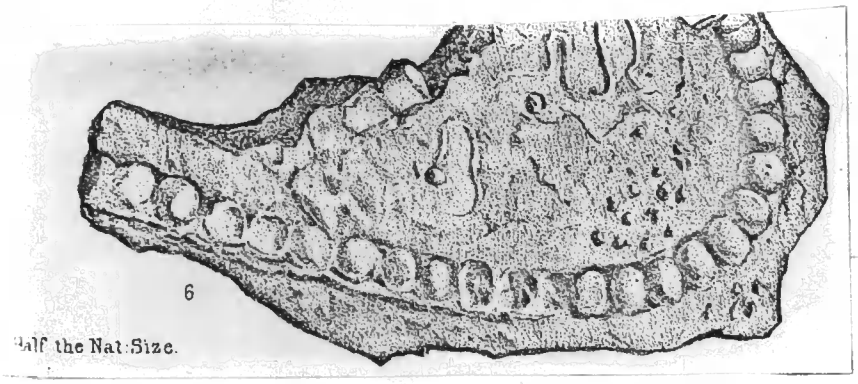
Plate Ten

Chondrites from the Middle Liassic Sandy Series

A. Preserved by bed-junction sedimentation, from a loose block north of Skinningrove.

B. Associated with Curvolithus and Entolium, preserved by bed-junction sedimentation accentuated by baking from the Cleveland Dyke; from Cliff Rigg Quarry, near Great Ayton.



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Half the Nat. Size.

Plate Nine

A. Eione moniliformis TATE G., a beaded trace fossil from the Namurian of Howick, Northumberland (type specimen)

B. Beaded trace fossil from Swath Beck Hush, Moor House National Nature Reserve, with sharp lateral ridges.

C. Related trace fossil from same locality lacking a beaded appearance and possessing pronounced lateral ridges.

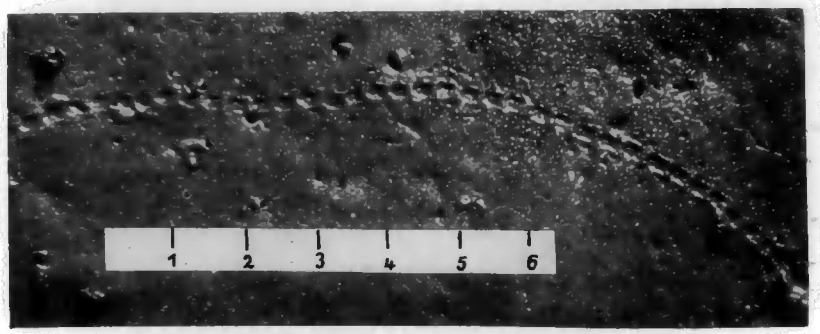
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Plate Eight

A. Close-up of typical beaded trail of the amphipod Corophium volutator, preserved in mud with low thixotropy.

B. General view of a set of Recent trails of Corophium volutator, showing unbeaded areas caused by subsequent thixotropic flow.

Plate Fourteen

A. Close-up of a vertical section showing the "sagging" of the laminae on the inside of the 'U'.
Note the depressed laminae of the inhalent and the plugged tube of the exhalent limb of the burrow to the left.

B. Plan view of a horizontal section showing the slit-like cross-section of the burrows.

Plate Twelve

Oblique view of loose block of laminated sandstone (S.B.35) from the Scarborough Beds of Ravenscar, showing both vertical and horizontal aspects of *Arenicolites statheri* BATHER.

Plate Thirteen

View of vertical face of sandstone, showing *Arenicolites statheri* descending from the plane of a small unconformity.
Note the solid tube-casts in many of the burrows.

The hammer = 38 cm. in length.

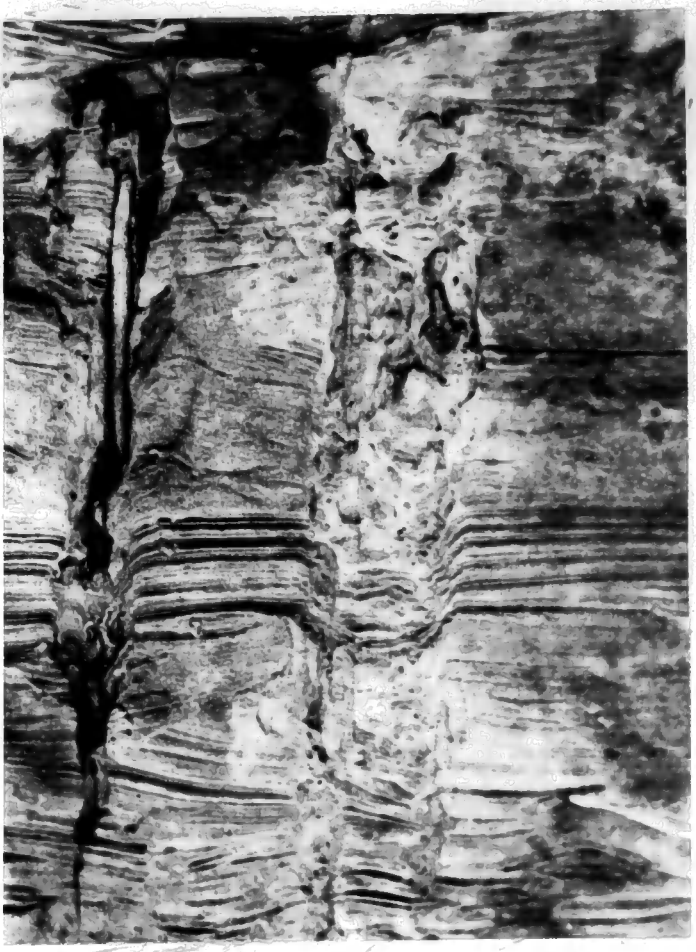


Plate Fifteen

A. Calcareous gritstone dogger from the Bencliff Grits east of Osmington Mills showing slump structure associated with an immediately post-depositional fracture.

B. Calcareous gritstone dogger from the Bencliff Grits on the backshore just west of Redcliff Point, showing deeply eroded slots of Diplocraterion arkelli sp.nov. Note the large size, and dumbbell-shaped cross-section. x 0.15

C. Smaller examples of retrusive Diplocraterion arkelli associated with sharp linguoid ripples. Note the smaller size, sausage-shaped cross-section, and lower density. x 0.08

Plate Sixteen

A.

Vertical section of *Diplocraterion arkelli* from Nothe Grits of Bowleaze Cove showing the strong *Spreite* and indistinct limbs. x $\frac{1}{3}$

B.

Horizontal section showing ringed aperture and faecal pellets. x 1

C.

Vertical section across *Spreite* with retrusive laminae. x 1

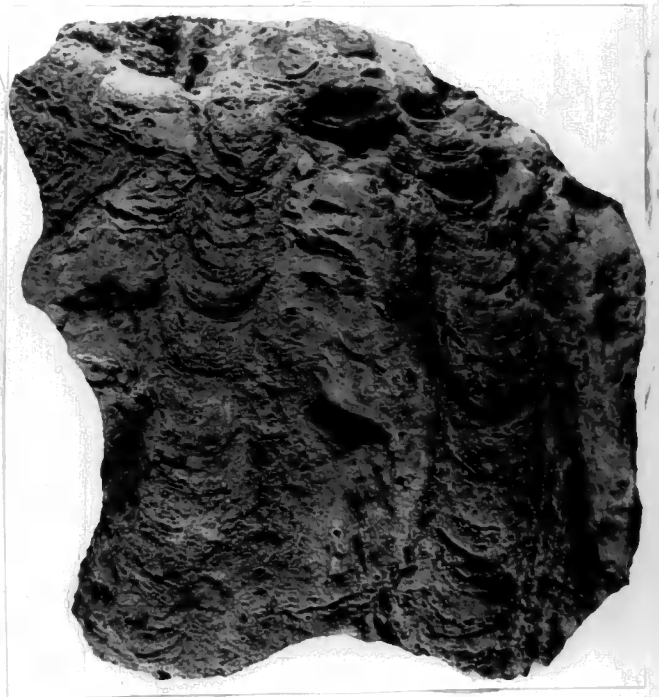


Plate Seventeen

Large loose block of sandy limestone (S.S.28) from the Scarborough Beds on the backshore at Iron Scar, with retrusive *Diplocraterion arkelli* occurring in high densities.

Plate Eighteen (A)

Diplocraterion statheri sp. nov. from a large loose block of sideritic sandstone from the Dogger in Saltwick Bay, near Whitby; maximum burrow density recorded.

Plate Eighteen (3)

Diplocraterion statheri at intermediate density;

Old Nab, Saltwick Bay.

Plate Eighteen (C)

Diplocraterion statheri at low density;

beneath Whitby High Light.

Plate Nineteen

Ironstone nodules from the base of the Ellerbeck Bed with Corophioides lymensis (COYSH)

A. Associated with oblique Rhizocorallium jenense ZENKER and Chondrites.

B. Showing the delicate transverse striae, and the 'key-hole'-shaped crossection.

In each specimen, notice the striking contrast with the white kaolinitic, soft, silts of the Lower Deltaic Series. x $\frac{3}{4}$

Plate Nineteen (1)

Rhizocorallium (Corophioides) jenense ZENKER; vertical crustacean burrows descending from the base of the Dogger into the Alum Shales in Long Bight, East Cliff, Whitby.

A.

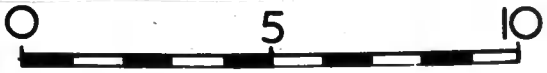
Vertical face showing the coarsely scratched Spreite on the right, and slickensided shale with selenite crystals on the left.

B.

Slickensiding along the burrow sides of basal 'U'

C.

Basal 'U' of large burrow showing the very coarse scratches on limbs and Spreite



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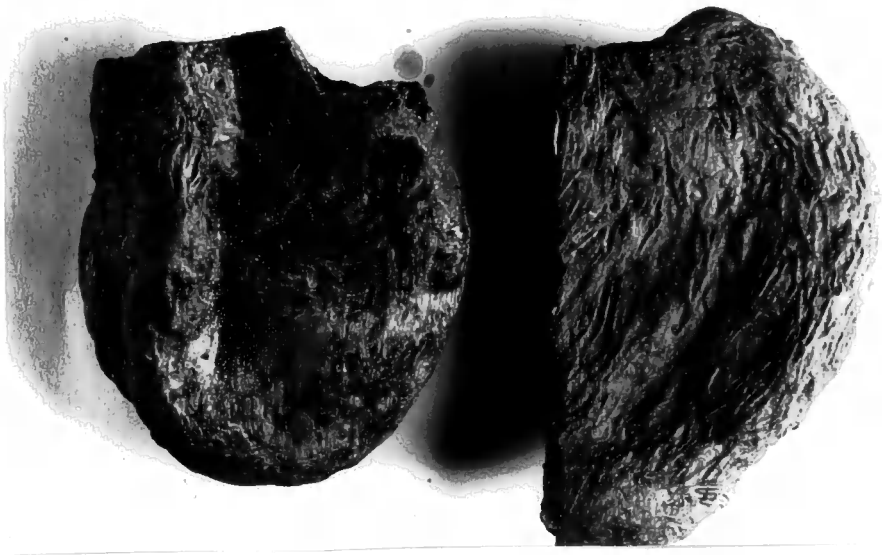

Plate Twenty

Skolithos c.f. linearis HALDEMAN from Bed 6 of the Osmington Oolites, Black Head.

A. Burrows descending perpendicularly with respect to a cross-set of strata.
To the left of the photograph, burrows with bed-junction preservation; to the right, above the hammer-head, concealed bed-junction preservation.

B. Closeup of vertical face of oolite, showing concealed bed - junction preservation.

C. Horizontal section through the burrows of B) showing their circular cross-section, and coarsely oolitic filling.

Plate Twenty-five

Close-up of *Thalassinoides suevicus* from the condensed Hambleton Colite Series of Filey Brigg. Notice the bleached nature of the burrows compared with the matrix, where serpulids and *Exogyra* are very abundant.

Near the fountain-pen (length= 13 cm.) one burrow may be seen cutting another. Normally they anastomose.

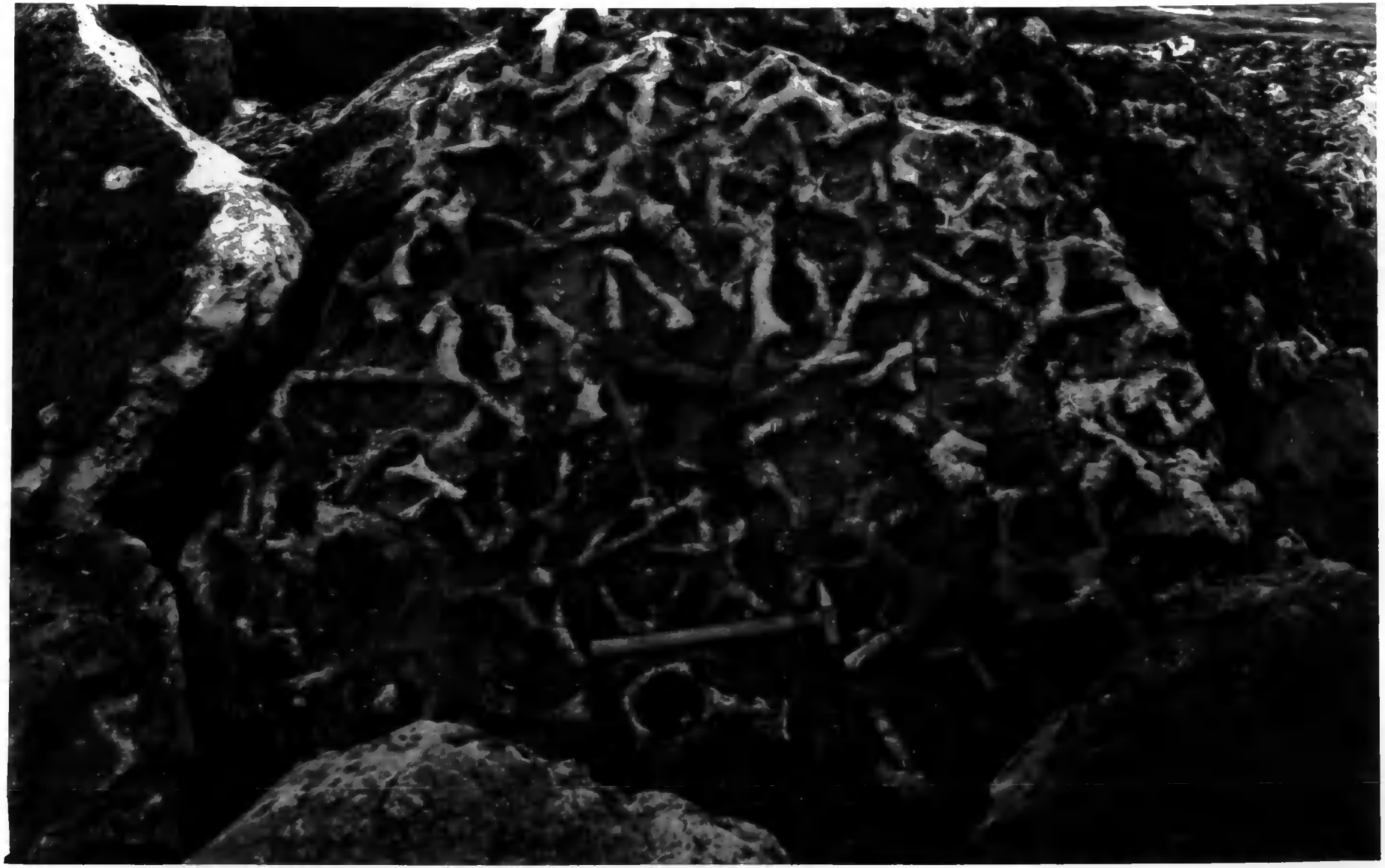

Plate Twenty-four

Thalassinoides suevicus preserved as white, horizontal Y-shaped burrows set in brown calcareous grit; loose block of Hambleton Oolite on Filey Brigg.

Plate Twenty-three

A. large Thalassinoides suevicus (QUEN.) from the Trigonia hudlestoni Bed, Redcliff Point, showing the dichotomous branching and peripheral furrows, where loosely compacted shelly matter has been removed by erosion.

Burrow width = 5 cm.

B. isolated burrow system of Thalassinoides suevicus in sandy limestone (S.B.28) from the Scarborough Beds; Cloughton Wyke (54/020951). Note the very regular dichotomy.

Teichichnus accounts for 90% of the ichnofauna

Plate Twenty-two

Essentially horizontal hummocky masses of Thalassinoides saxonicus (GEIN.) from coarse calcareous grit (S.B.28) of the Scarborough Beds; loose block on the backshore south-southeast of Blea Wyke (45/993012).

Note the annelid-like axial core running through many of the burrows.

Plate Twenty-one

Ophiomorpha borneensis KEIJ from the Corallian

A. From the Bencliff Grit of Redcliff Point, showing the wart-like lining of the burrows.

B. From Bed 6 of the Osmington Oolites of Black Head, showing the eroded lining, smooth core, and dichotomous branching.

C. From Bed 7b of the Osmington Oolites of Black Head, showing the regular pits along the burrow margins.

Plate Twenty-six

Rhizocorallium cicatricosus (TATE & BLAKE) from the Main Seam of the Middle Lias Ironstone Series, Old Nab, southeast of Staithes (45/794187); bed 52 of HOWARTH (1955).

Notice the apparent absence of Spreite, the area being highly disturbed by Chondrites, and the lacerated limbs.

Specimen whitened with ammonium chloride.

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Plate Twenty-five (1)

View of an Ellerbeck Bed ironstone nodule from beneath, showing the Spreite of an oblique Rhizocorallium jenense ZENKER, and many 'key-hole' cross-sections of Corophioides lymensis (COYON)

Notice the starting bed-junction preservation, and the great detail of the Spreiten sculpture.

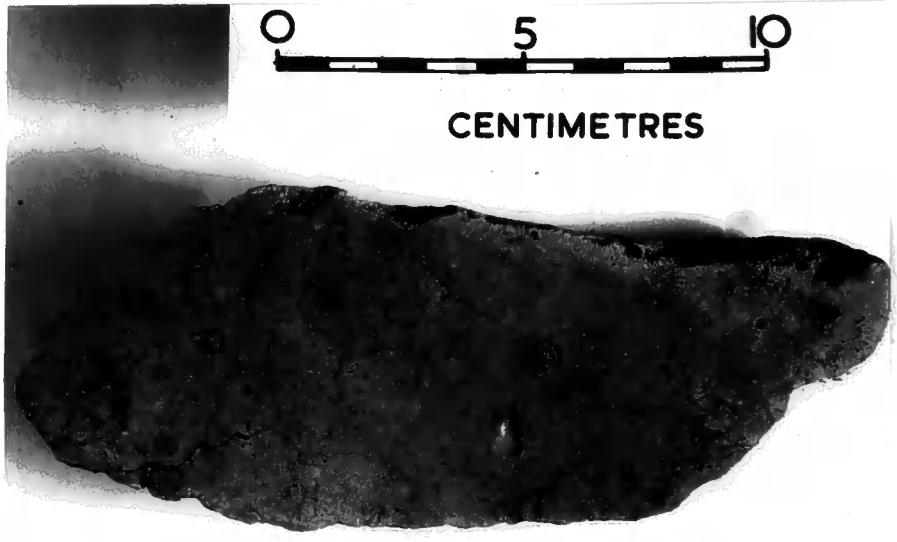
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Plate Twenty-seven

A.

Rhizocorallium cicatricosus

showing U-shaped vertex and

absence of Spreite.

Locality as in Pl.26

C.

Rhizocorallium

cicatricosus ,

showing very long

flexuous burrow

and thick limbs.

Loc. as in Pl.26

B.

Small initial section of

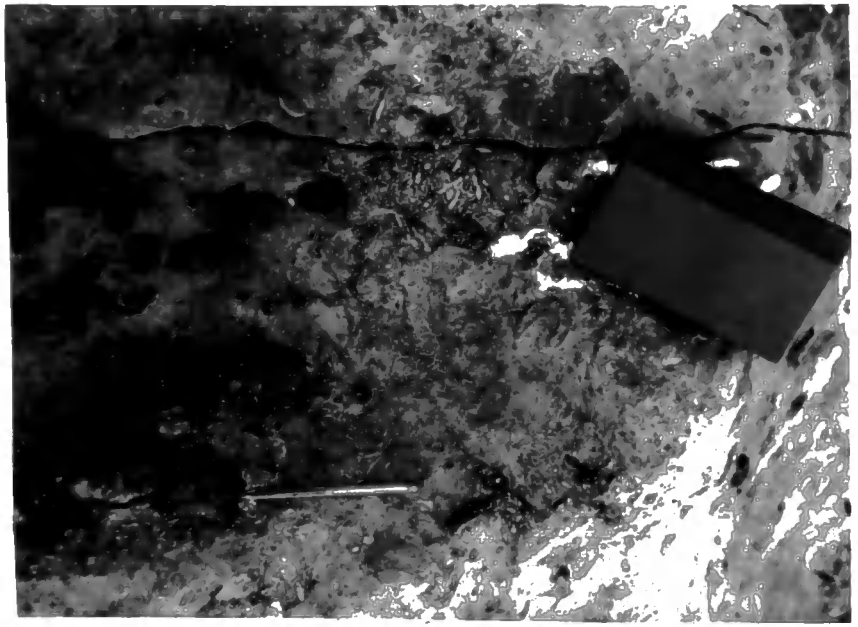
Rhizocorallium commune SCHMIDT

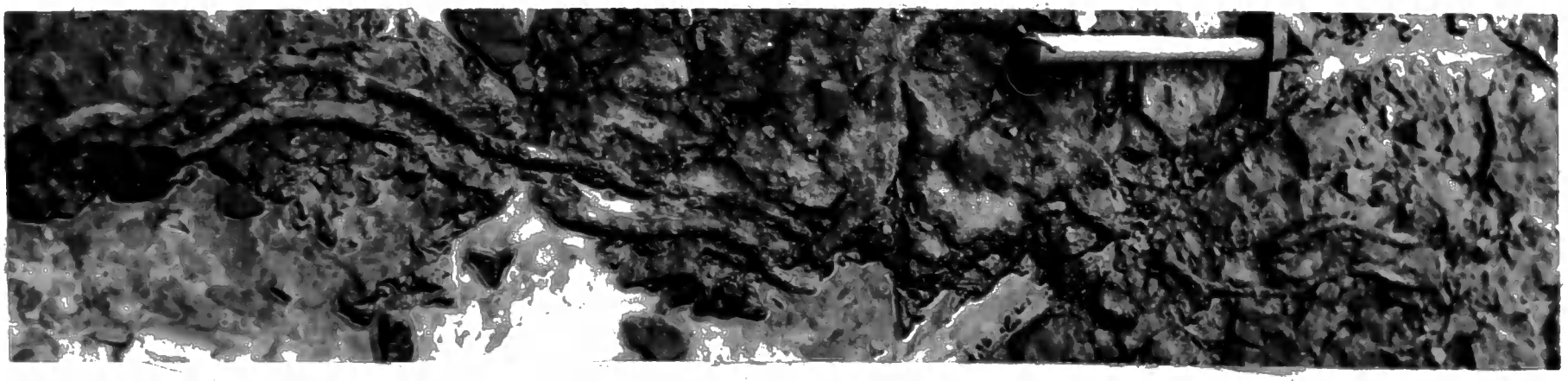
associated with Taenidium,

Chondrites, serpulid colonies

and Pinna (vertical); Grey Beds

(Beds 80 of DEAN 1954); Peak.





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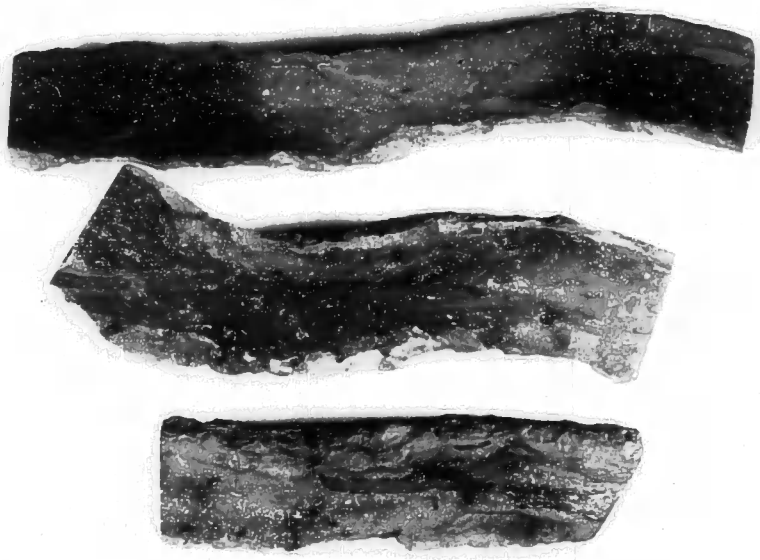


Plate Thirty

Polished sections of *Rhizocorallium cicatricosus*.

A. Vertical transverse section showing the siderite-plugged limbs which appear mottled with faecal pellets.

B. Horizontal longitudinal section showing irregularly ellipsoidal faecal matter (in the top limb) and *Chondrites* in the lower two limbs.

Locality as in Plate 26

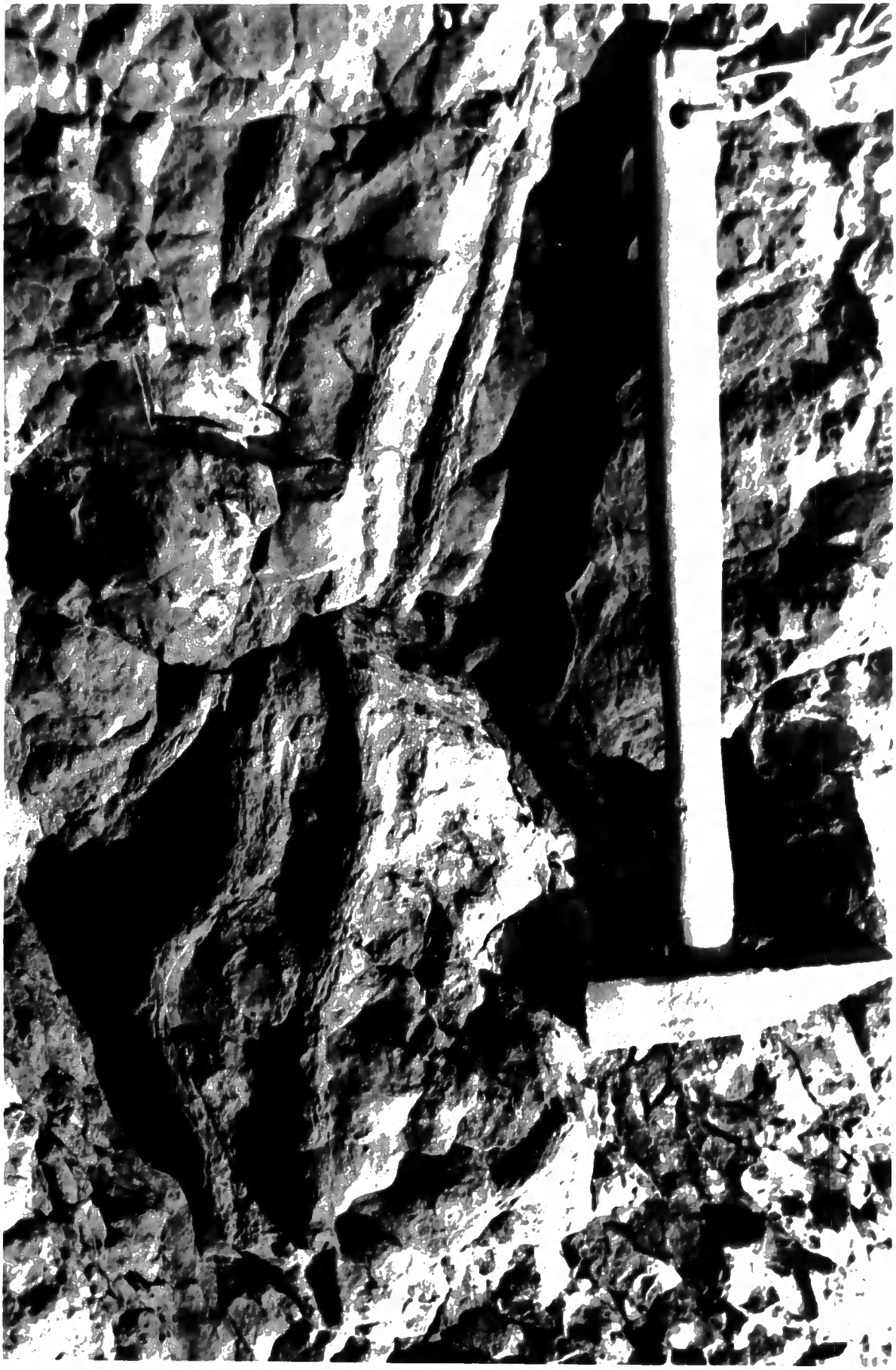


Plate Twenty-eight

Rhizocorallium cicatricosus with 'kink' in the return limb caused by a vertical obstruction.

Locality as in Plate 26 x $\frac{1}{2}$

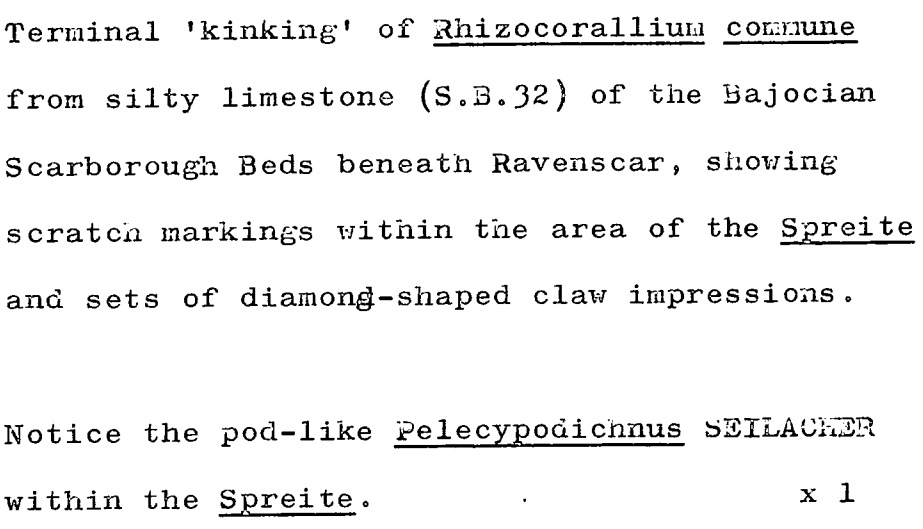
Plate Thirty-one

Succession of burrows of Rhizocorallium commune from argillaceous limestone with symmetrical ripple-marks (wavelength = $3\frac{1}{2}$ "); Scarborough Beds (S.B.32) beneath Ravenscar.

Note the different ethological patterns of successive burrows.

(See also Text-figure 29)

Plate Thirty-two



Terminal 'kinking' of Rhizocorallium commune from silty limestone (S.B.32) of the Bajocian Scarborough Beds beneath Ravenscar, showing scratch markings within the area of the Spreite and sets of diamond-shaped claw impressions.

Notice the pod-like Pelecypodichnus SEILACHER within the Spreite. x 1

Plate Thirty-three

The Recent stomatopod crustacean *Squilla serrata*, one of the few organisms known to produce *Rhizocorallium*-like structures at the present-day.

Note the six-pointed sub-chelae. x $1\frac{1}{2}$

Plate Thirty-four

A. Typical orthodox Rhizocorallium commune from silty limestone (S.B.32) of the Scarborough Beds from beneath Ravenscar showing the narrow, lacerated limbs; poorly developed Spreite; and remarkably constant gauge.

B. Slightly oblique vertical transverse section of Rhizocorallium (probably R. cicatricosus) from the Middle Band of the Main Seam of the Ironstone Series at North Skelton Mine, showing the siderite-plugged limbs and well-developed Spreite filled with opaline ooliths.

The matrix is dominantly siderite mudstone highly burrowed by Chondrites.

N.B. The object just beneath, and to the left of the Spreite, is an ammonite chamber.

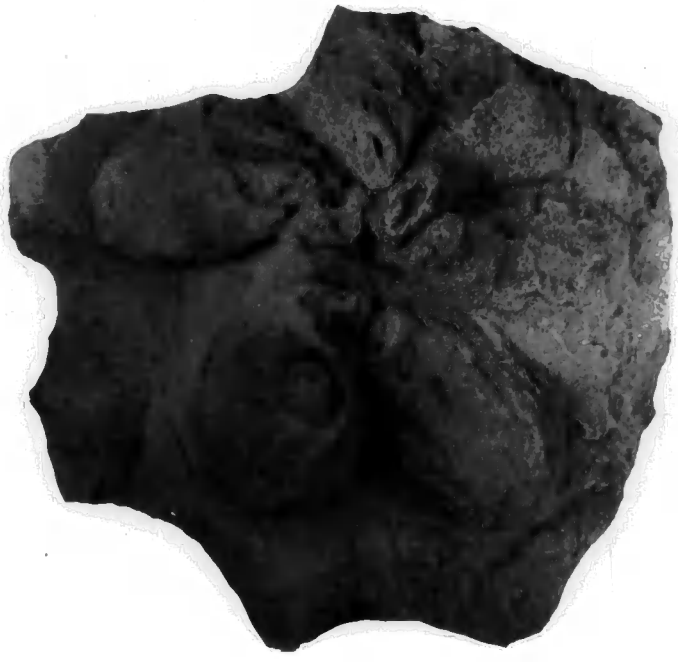


Plate Thirty-five

Asterosoma fosteri sp. nov. from the Dogger of Loop Wyke, northwest of Whitby.

A. Plan view showing the radiating lobes

B. Side view showing the strongly raised centre and the flat lobe profile.

x $\frac{2}{3}$

Plate Thirty-six

A.

Radially incomplete Asterosoma c.f. radiciforme from sandy limestone (S.B.32) beneath Ravenscar x $\frac{1}{3}$

B.

Radially complete example, distinctly ovoid in outline beneath Beast Cliff.

C.

Oblique view of Asterosoma multilobatum sp. nov. from sandy limestone (S.B.28); Cloughton Wyke (54/993012). Note the large number of lobes in very high relief.

Plate Thirty-seven

Chondrites from the upper block of the Main Seam at Old Nab, southeast of Staithes (45/794187). Bed 54 of HOWARTH (1955) x 6

Plate Thirty-nine

A. Pinnate branching of Chondrites in very coarse conglomeratic Middle Lias sandstone from Chideock, Dorset; associated by "Cylindrites" Note the occurrence of the Chlamys shell. x 1

B. Chondrites within the shell of a decalcified bivalve from the Blea Wyke Beds of Peak. x 5

Plate Thirty-eight

Chondrites from coarse grey siltstone of Ironstone Series (Bed 41 of HOWARTH 1955); Hawsker Bottoms (45/952076); showing tunnel systems of two sizes. Note the constriction in tube diameter at the point of branching in the larger system. x 5

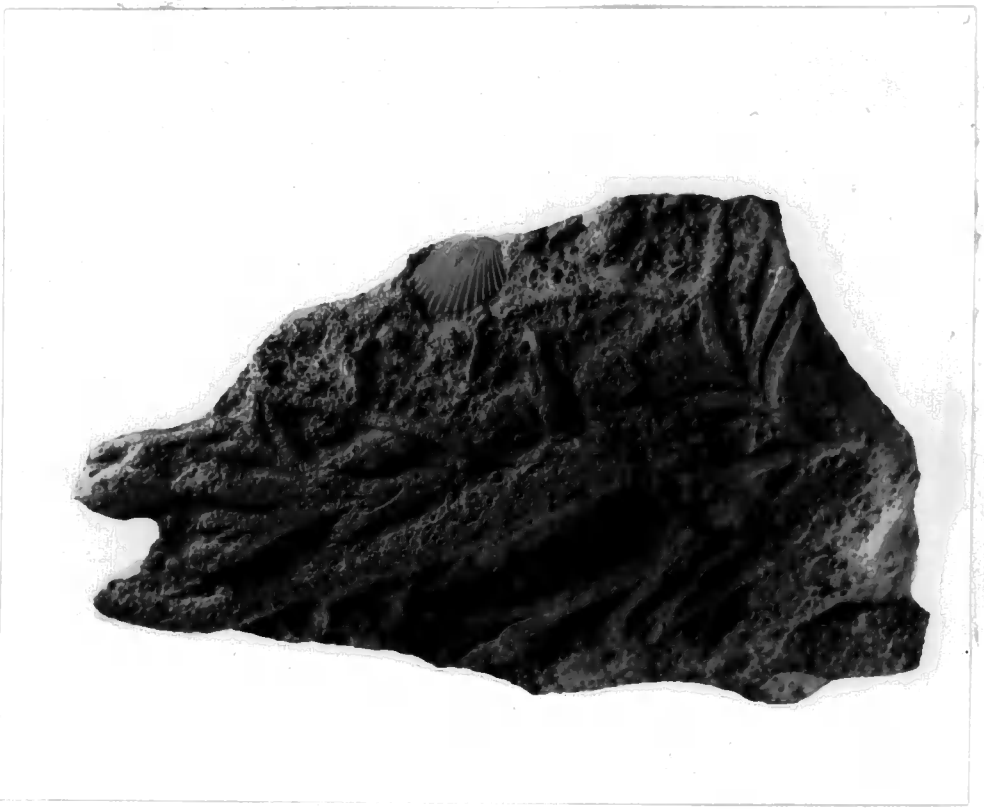


Plate Forty

Teichichnus from fine-grained sandy limestone (S.B.32) beneath Beast Cliff, Ravenscar.

A.

Example with 5 cm. vertical development and horizontal translation.

B.

Example with 3 cm. vertical development and no translation.

C.

Recent trace of Nereis, caused by the lateral migration of several dwelling tubes (SCHAFER)

D.

T-shaped apparent intersection of two Teichichnus.
Locality as in A) and B)

Abb. 214. Gepreßte Schlicklamellen, entstanden durch seitlichen Versatz von mehreren Wohnröhren von *Nereis*. Freigespült widerstehen sie der Zerstörung länger als das umgebende Sediment. — Original.

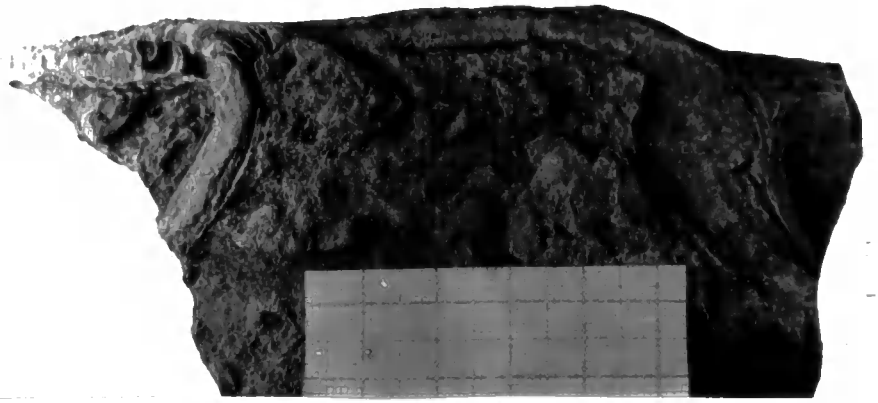


Plate Forty-one

A. Teichichnus associated with general spiral disturbance of surrounding sediment.

B. Oblique Teichichnus associated with horizontal Gyrochorte c.f. comosa HEER.

Locality and horizon as Plate 40A.

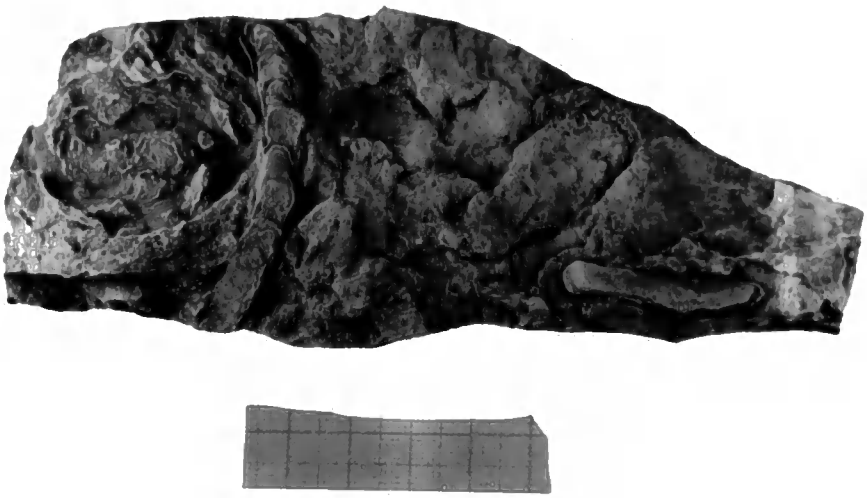


Plate Forty-two

Planolites ophthalmoides JESSEN from loose block of grey, fine-grained deltaic sandstone with rib-and-furrow structure; beneath Ravenscar.

Plate Forty-three

A. Loose block of cross-laminated sandstone (? Lower Deltaic Series) beneath Ravenscar, with aggregations of faecal pellets.

B. Close-up of the faecal pellets. Notice the impressions of many smaller pellets which have been removed by erosion.

Plate Forty-four

Recent crab pellets in two sizes (KREJCI-GRAF) from tropical shores around Hong Kong. Larger pellets identical in size to those illustrated on Plate 43.

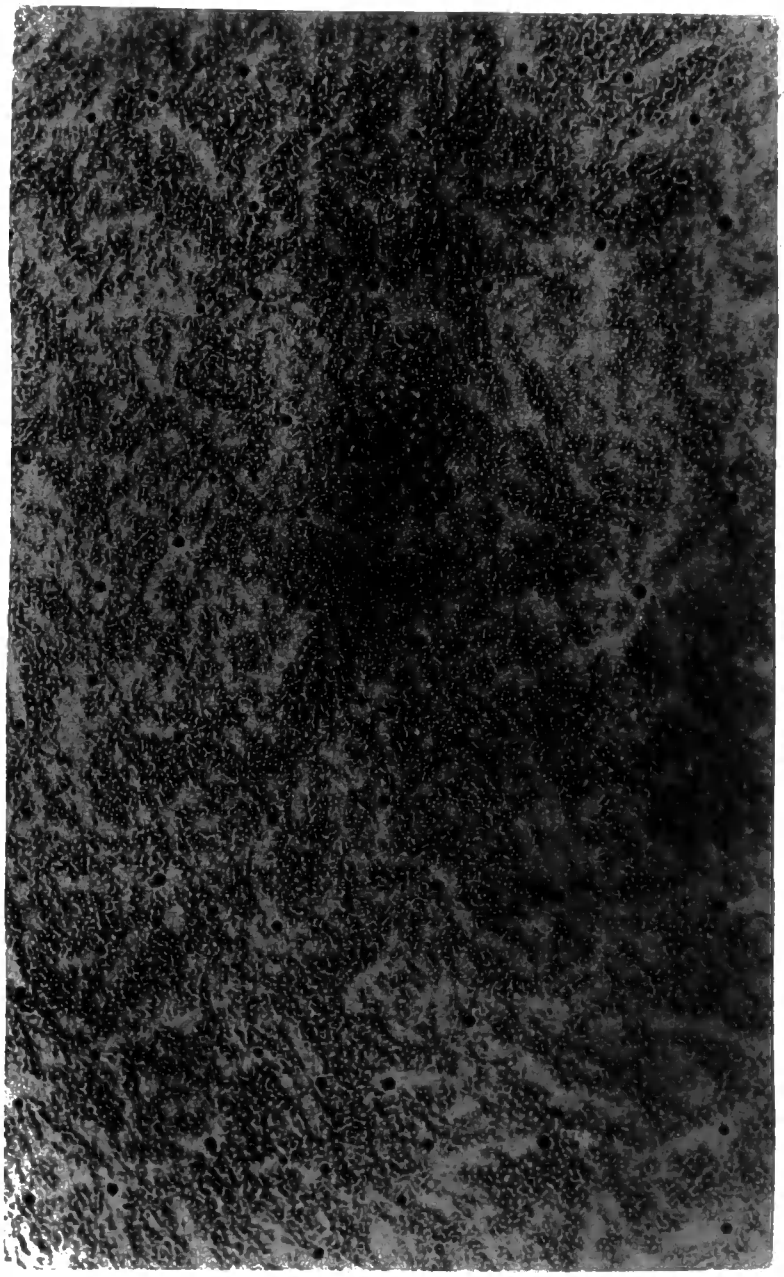
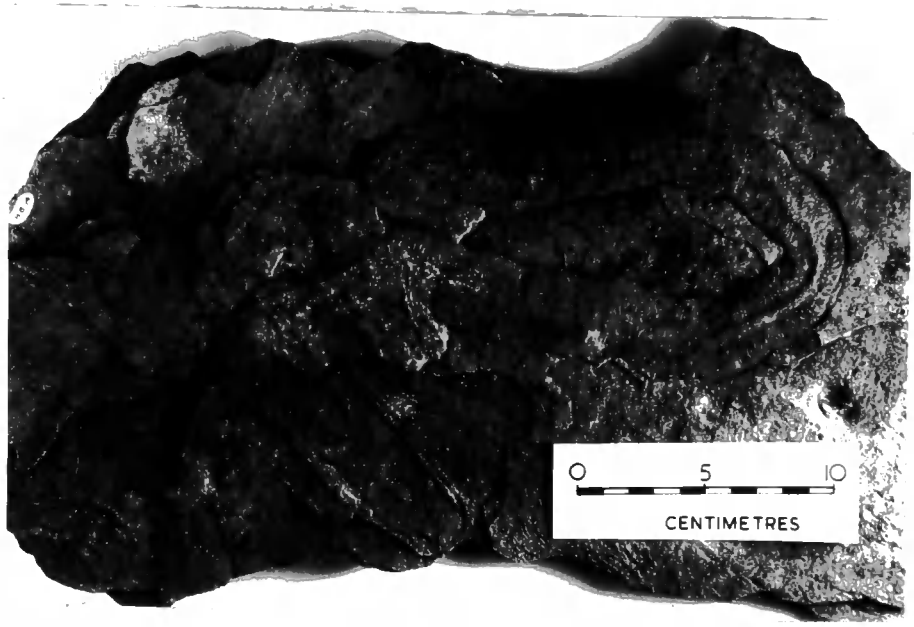


Plate Forty-five

Two loose blocks of deltaic sandstone with *Gyrochorte carbonaria* SCHLEICHER and the pod-like *Pelecypodichnus* SEILACHER.



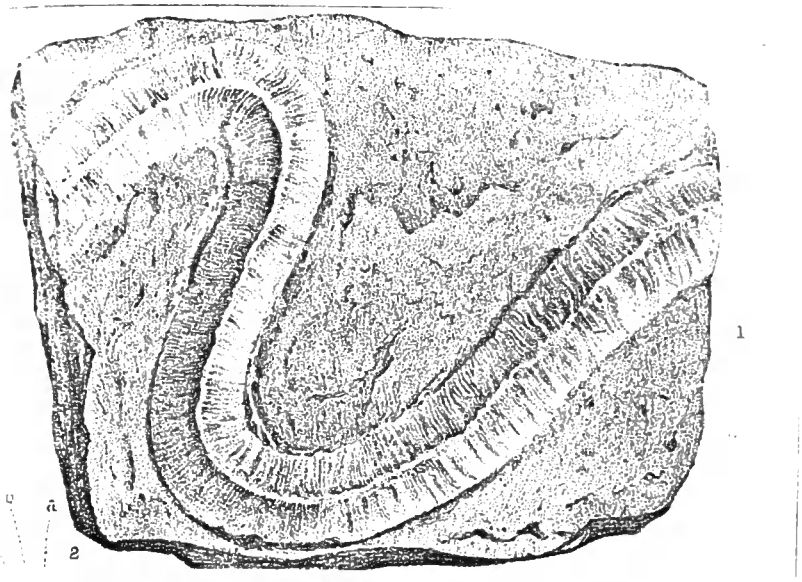


Plate Forty-five (1)

The Namurian trace fossil Crossopodia embletonia TATE G. from Northumberland, an example of the Pascichnia, which are completely absent from the Jurassic.

Plate Forty-six

Sandstone with symmetrical ripple-marks (S.B.35) from the Scarborough Beds below Ravenscar showing randomly oriented Gyrochorte carbomaria.


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Plate Forty-seven

Gyrochorte carbonaria SCHLEICHER

A. Examples from the Ellerbeck Bed of Goathland trending parallel to the crests of symmetrical ripple-marks.

B. Examples from laminated siltstones with parting lineation from the Namurian of Haltwhistle Burn, Northumberland showing the pronounced orientation of the trails.

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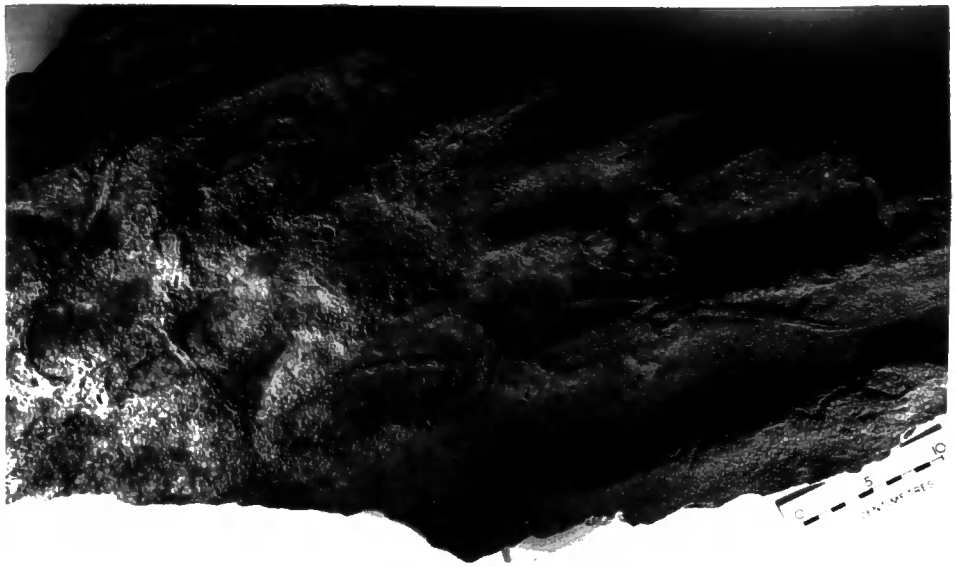
CENTIMETRES

Plate Forty-seven

C. U-shaped Gyrochorte carbonaria oriented at right-angles to the parting lineation.

D. Two U-turns developed in adjacent trails; oriented at right-angles to parting lineation.

Both examples from the Carboniferous of Haltwhistle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CENTIMETERS

Plate Forty-eight

Two broad U-turns developed by adjacent Gyrochorte trails in ripple-marked sandstone from the Ellerbeck Bed of Goathland.

Plate Fifty-one

Hundale Point seen from the cliffs above Cloughton Wyke.

The scar is formed by the thick sandstone above which occur the Scarborough Beds.

Plate Fifty

Trough cross-lamination in the basal sandstone of the Scarborough Beds (S.B.36); *in situ* at (45/990010).

The notebook is 16 cm. in length.

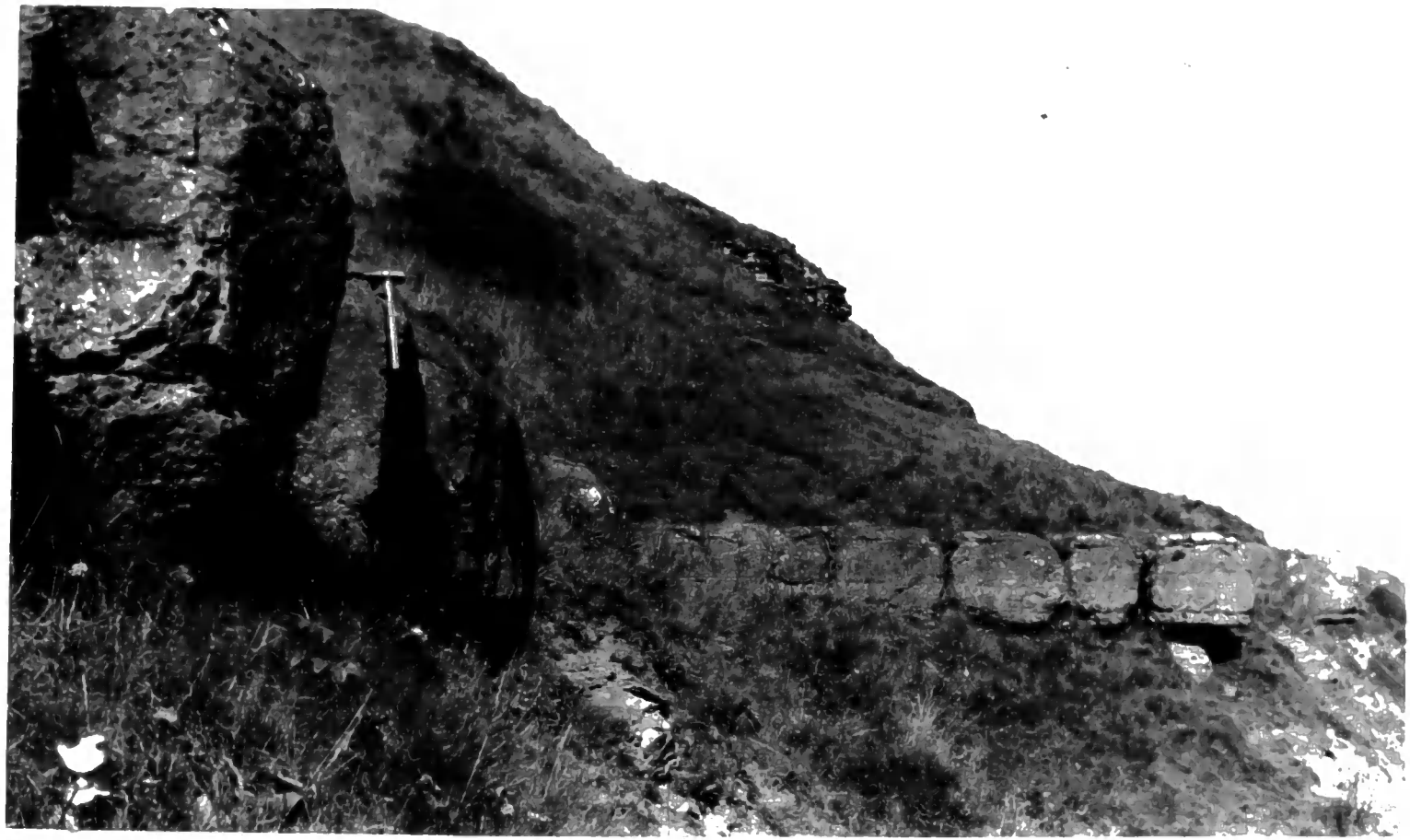


Plate Forty-nine

The outcrop of the Scarborough Beds in the cliffs to the southeast of Blea Wyke Point (45/990010) showing the sphaeroidal weathering of the coarse calcareous grit member (S.B.28) on which the hammer rests, the sandstones at the top of the succession, and the impure limestones, in the foreground. The gently sloping part of the cliff is formed by the thick shale member (S.B.27).

Plate Fifty-three

A. Bowleaze Cove; cliffs west of Redcliff Point; showing prominent feature made by the large tabular blocks of the Trigonia hudlestoni Bed.

B. Bed 7b of the Osmington Oolite, Black Head; showing "churned" limestone overlain by massive oolite. The horizontal hollows are cross-sections of Ophiomorpha borneensis. In situ photograph.

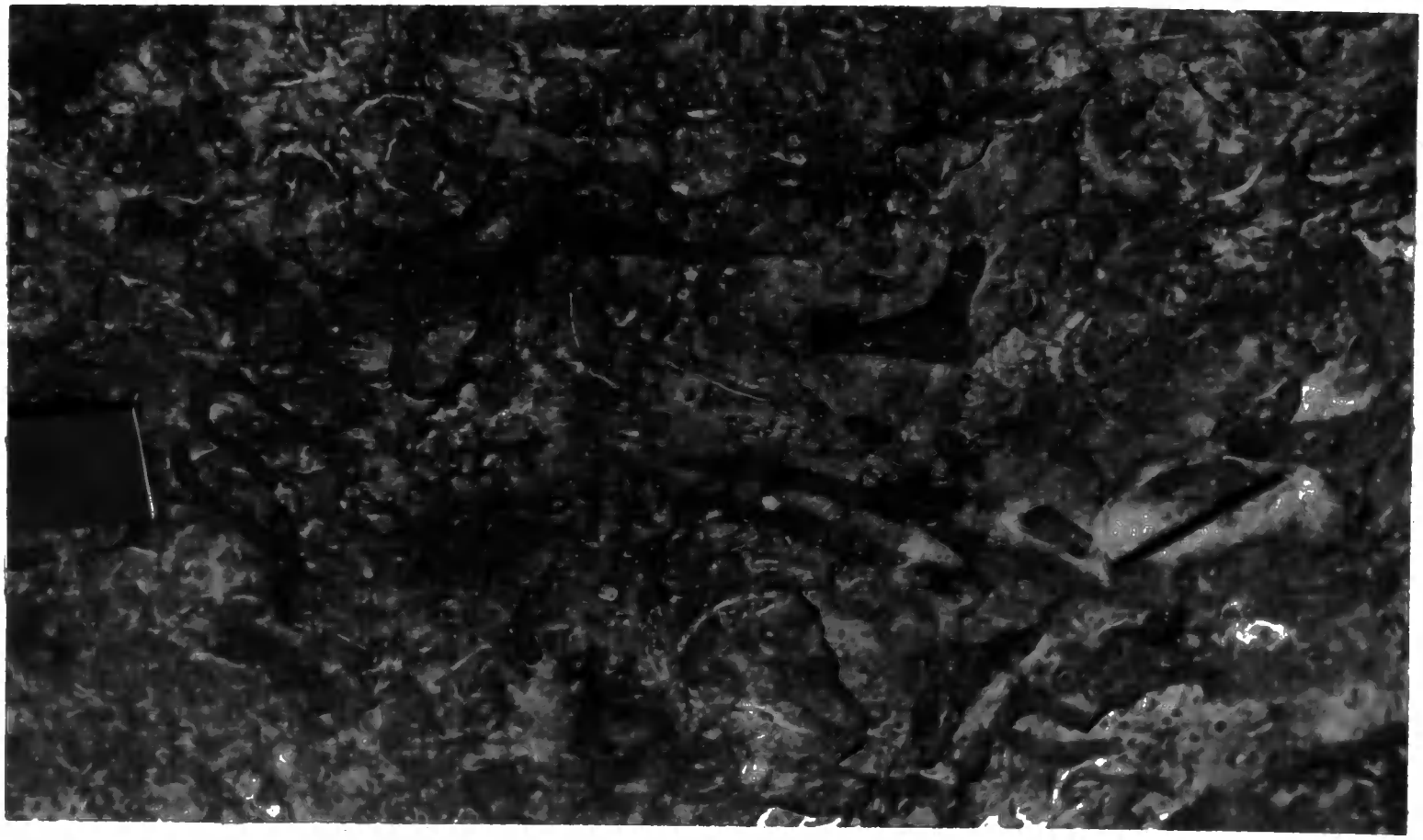


Plate Fifty-two

Mixed trace-fossil assemblage in sandy limestone from the Scarborough Beds at Iron Scar; dominated by Teichichnus, but with ferruginous Thalassinoides suevicus and Rhizocorallium commune.

Pencil = 12 cm. in length

APPENDIX LV : MEASURED SECTION OF STRATA THROUGH THE BAJOCIAN SCARBOROUGH BEDS ¾ MILE SOUTHEAST OF RAVENSCAR STATION

e)	Bleached sandstone, flaggy, grey, micaceous	2' 10"	
d)	Ferruginous flaggy sandstone	9"	
c)	Grey micaceous siltstone parting	½"	
b)	Flaggy siltstone	3½"	Astarte minima, Meleagrinella lycetti, Catinula sp. ; rare
a)	Gritty siltstone parting	½"	
1)	Sandy shale with ironstone	4½"	
2)	Brown, micaceous, flaggy sandstone	2"	Chlamys common; Pleuromya casts; Modiolus; gastropods indet. rare
3)	White, flaggy sandstone	6-9"	Chlamys rare; Catinula rare-common
4)	Grey, laminated silts	8"	Pleuromya casts, Catinula common
5)	Grey, flaggy siltstone with plant debris at top; ramified by "worm tubes"	7"	Catinula, M.lycetti, Pterocardia rare
6)	Massive ferruginous sandstone with boxstone rim; burrows from 5)	1' 1"	Catinula, M.lycetti, Pleuromya casts very common
7)	Grey siltstone; ramified by horizontal "worm tubes"	3-5"	
8)	Iron Pan	½"	
9)	Ferruginous siltstone; small vertical tubes at base	6½"	
10)	Iron Pan	¼"	
11)	Grey siltstone; ramified by horizontal "worm tubes" in 2" clusters	4"	M.lycetti, Lima rare
12)	Iron Pan	¼"	
13)	Grey, finely-laminated siltstone; ramified by horizontal "worm tubes"	3"	
14)	Iron Pan	¼"	
15)	Grey siltstone; infested with "worm tubes"	6"	
16)	White, flaggy sandstone	2-3"	M.lycetti rare
17)	Massive brown sandstone with boxstone rim	8"	monotypic M.lycetti very common
18)	Grey siltstone; ramified by "worm tubes"	2"	
19)	Iron Pan	¼"	
20)	Grey sandy siltstone, cross-laminated; fewer burrows	4-7"	
21)	Iron Pan, persistent	½"	
22)	Grey sandy siltstone; few burrows	3"	
23)	Iron Pan	¼"	
24)	Grey siltstone; infested with "worm tubes" of many types	3-5"	
25)	Massive ferruginous sandstone	7-10"	Chlamys common; Catinula, M.lycetti rare
26)	Sandy siltstone, cross-laminated; vertical burrows at base	6-8"	
27)	Silty shale	51' 0"	See TABLE 15 for details
28)	Calcareous grit	4' 0"	Rhizocorallium commune; no shelly fossils
29)	Purple-weathering, wavy-bedded limestone	2' 4"	Gervillella scarburgensis, Camptonectes lens, M.lycetti, belemnites
	c. Calcareous shale, very shelly	2' 0"	
30)	f. Nodular limestone full of pernids	5"	Gervillella, Isognomon very common; gregarious
	b. Calcareous shale	2' 2"	
	a. Black paper shale	1' 0"	
31)	Nodular flaggy limestone, very shelly	2' 0"	Astarte, Pteroperna very common
32)	Massive fine-grained sandy limestone, ripple-marked	2' 2"	Asterosoma c.f. radiciforme, Teichichnus; shelly fossils very rare
33)	b. Calcareous shales with irregular bedding	10"	Gervillella very common
	a. Carbonaceous ferruginous sandstone; extensive plant rootlets	9"	
34)	Black paper shales with thin siderite bands	2' 1"	
35)	Ripple-marked massive sandstone with U-shaped vertical burrows	5' 7"	Catinula, Pleuromya casts, M.lycetti along local erosion planes
36)	Massive sandstone with low-angle trough cross-bedding	4' 8"	Catinula rare

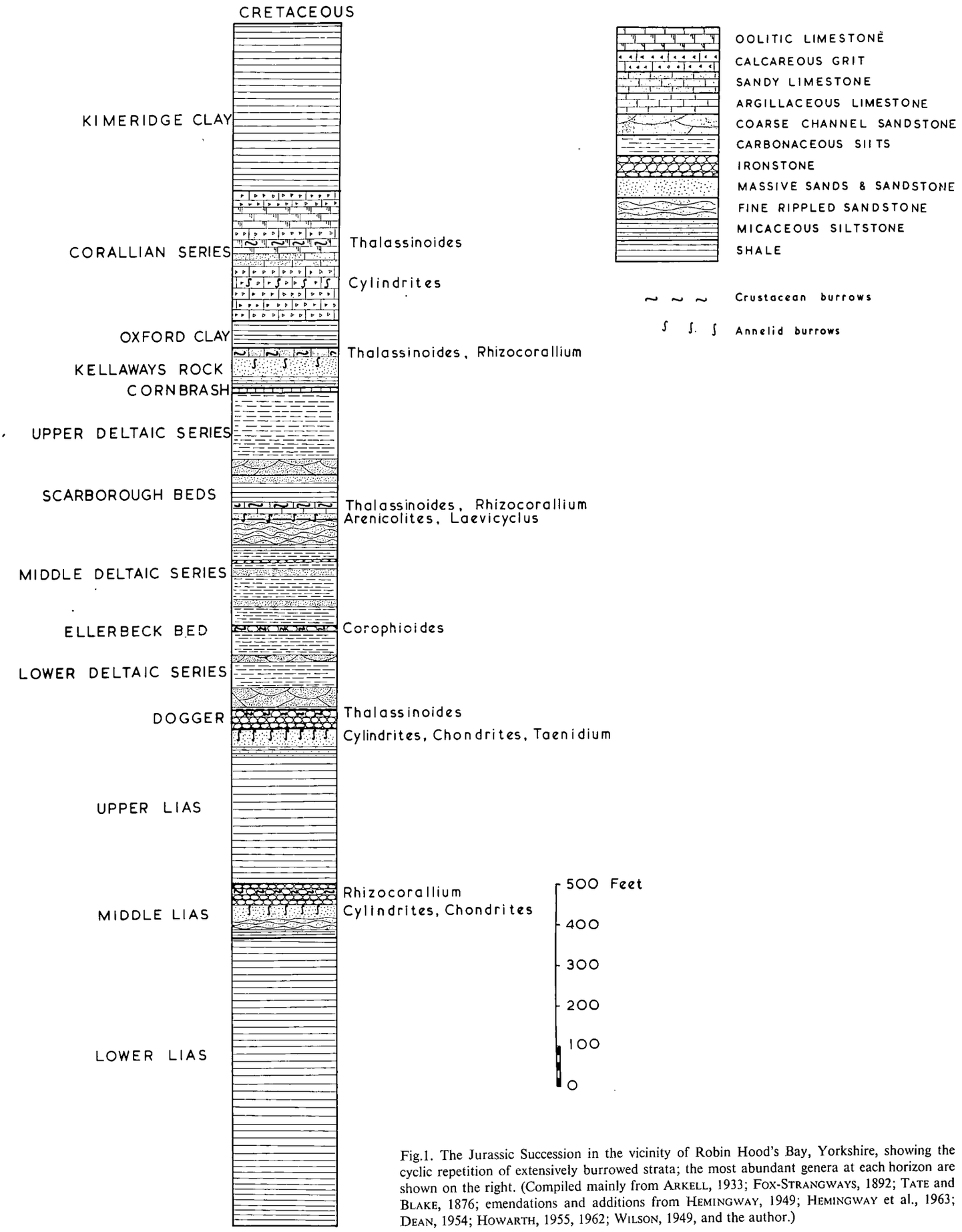
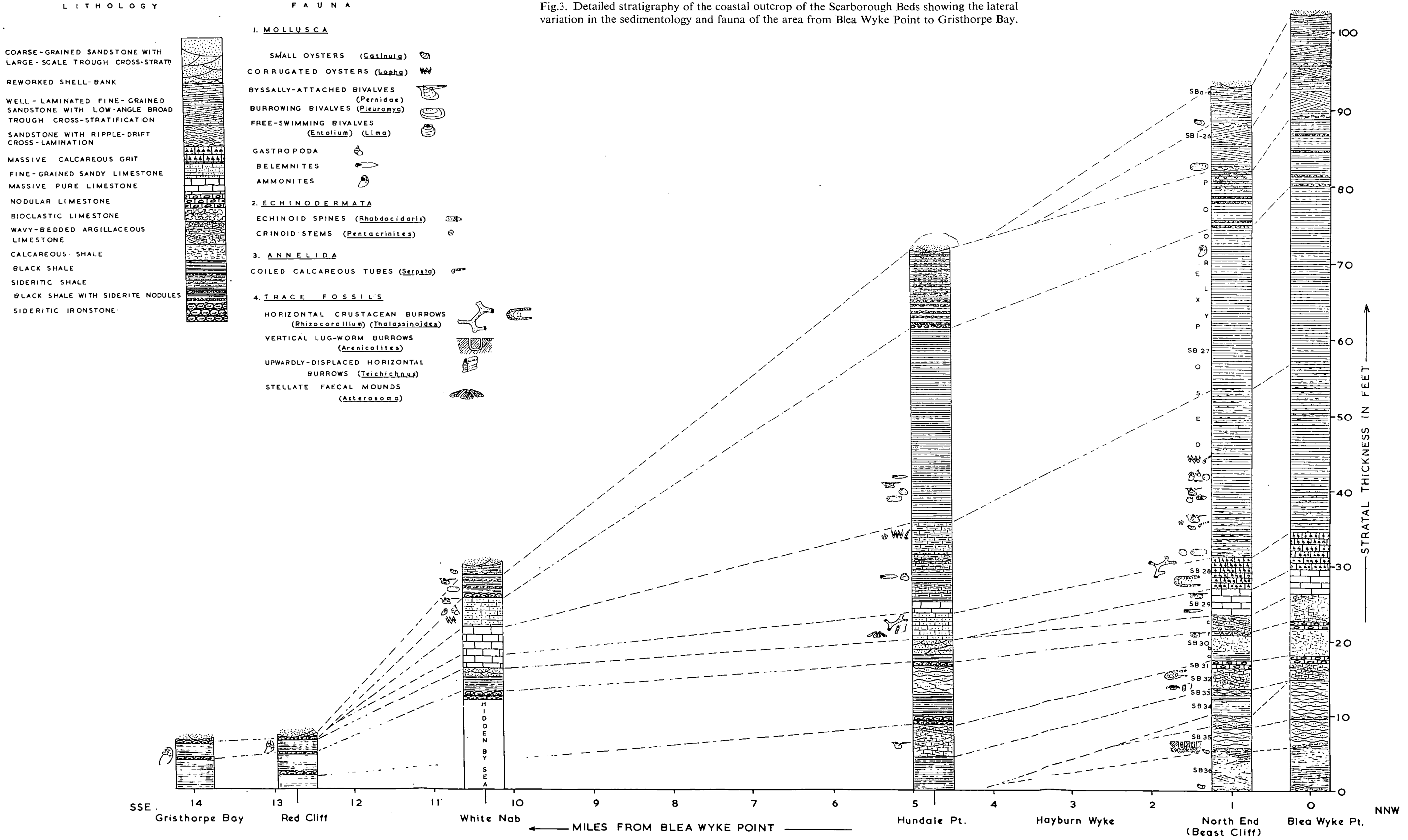


Fig.1. The Jurassic Succession in the vicinity of Robin Hood's Bay, Yorkshire, showing the cyclic repetition of extensively burrowed strata; the most abundant genera at each horizon are shown on the right. (Compiled mainly from ARKELL, 1933; FOX-STRANGWAYS, 1892; TATE and BLAKE, 1876; emendations and additions from HEMINGWAY, 1949; HEMINGWAY et al., 1963; DEAN, 1954; HOWARTH, 1955, 1962; WILSON, 1949, and the author.)

Fig.3. Detailed stratigraphy of the coastal outcrop of the Scarborough Beds showing the lateral variation in the sedimentology and fauna of the area from Blea Wyke Point to Gristhorpe Bay.



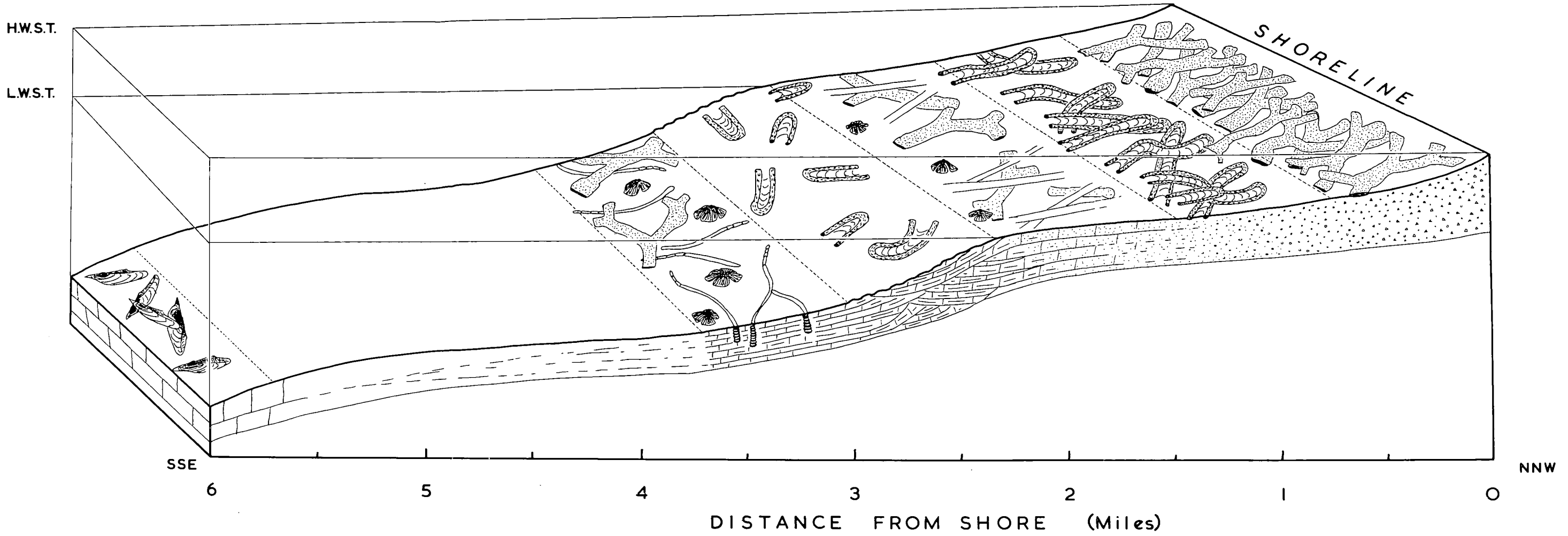
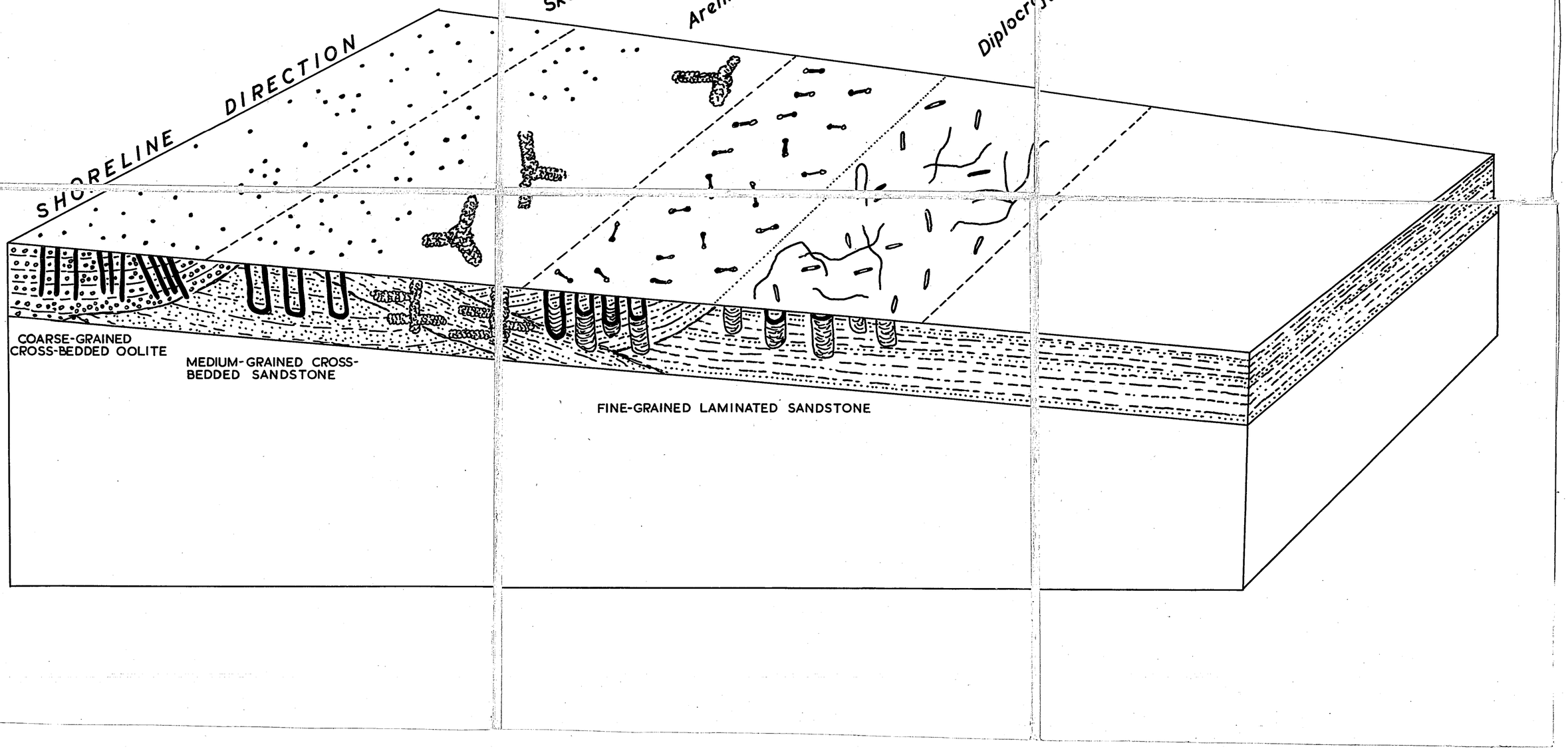


Fig.11. Suggested bathymetric zonation of the endobenthos in shallow-water limestones from the Bajocian Scarborough Beds of the Yorkshire coast. Compiled from stratigraphic data presented in Table III, Fig.10 and the text. (Horizontal scale accurate; vertical scale and lateral scale diagrammatic.)

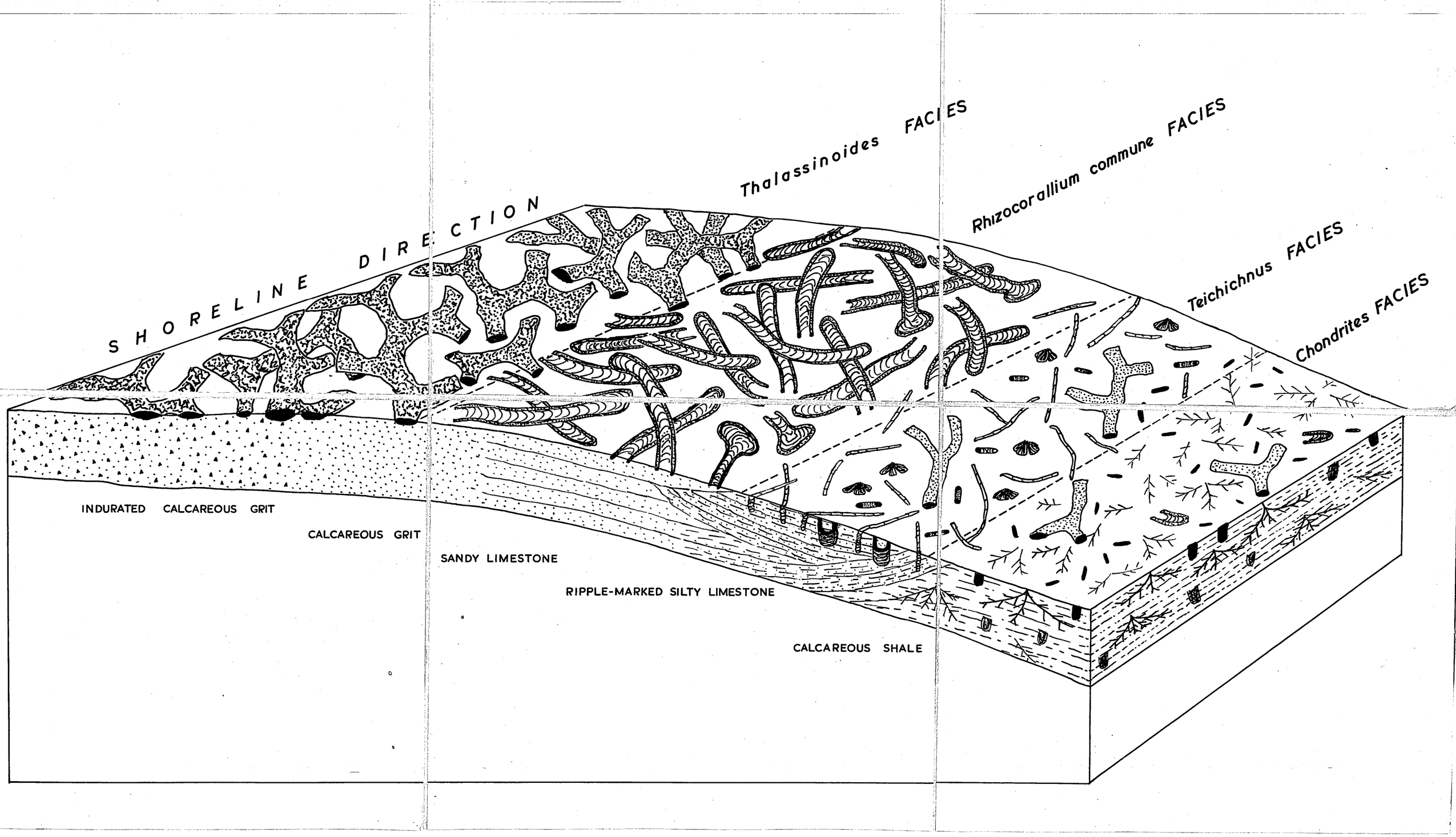
APPENDIX II : THE LITHOLOGICAL ASSOCIATION AND STRATIGRAPHIC DISTRIBUTION OF THE MAJOR TRACE FOSSILS FROM THE JURASSIC ROCKS OF ENGLAND

	Arenicolites	*Corophioides*	*Diplocraterion*	*Laevicyclus*	*Skolithos*	*Ophiomorpha*	*Rhizocorallium cicatricosus*	*Rhizocorallium commune*	*Teichichnus*	*Thalassinoides*	*Asterosoma*	*Chondrites*	*Planolites*
WELL-SORTED SANDSTONES & OOLITES													
Cross-bedded deltaic sandstone	x	x	x			x							
Trough cross-bedded sandstone	x	x			x								x
Laminated sandstone	x	x			x								x
Cross-bedded oolitic limestone				x		x							
IMPURE CALCAREOUS SEDIMENTS													
Marly oolitic limestone		x		x		x							
Calcareous shale		x					x	x			x		
Silty, ripple-marked limestone		x					x	x	x		x	x	
Sandy limestone		x					x	x	x			x	
Calcareous grit							x	x					
FERRUGINOUS SEDIMENTS													
Chamosite oolite							x						
Sideritic chamosite oolite							x				x		
Siderite mudstone	x		x				x				x		
Siltstone			x				x		x		x		
Shale			x				x		x		x		
UPPER JURASSIC	X	X		X		X	X		X		X	X	
MIDDLE JURASSIC	X	X	X		X		X		X		X	X	X
LOWER JURASSIC	X	X	X				X	X	X		X		
	DWELLING BURROWS					FEEDING						BURROWS	

TRACE-FOSSIL FACIES IN THE WELL-SORTED SANDSTONE AND OOLITE REGIME OF SEDIMENTATION



TRACE-FOSSIL FACIES IN THE IMPURE CALCAREOUS CLASTIC REGIME OF SEDIMENTATION



TRACE-FOSSIL FACIES IN THE IRONSTONE REGIME OF SEDIMENTATION